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R E P 0 R

RESEARCH PROJECT NM 12 01 T Subtask 5 Report No. 3

THE RATE AND MAGNITUDE OF EXPLOSIVE DECOMPRESSION REQUIRED TO PRODUCE LETHAL EFFECTS IN ALBINO RATS





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PENSACOLA, FLORIDA

NAVAL SCHOOL OF AVIATION MEDICINE, NAVAL AND THE PENSACOLA, PROBLEM

THE RATE AND MAGNITUDE OF EXPLOSIVE DECOMPRESSION REQUIRED TO PRODUCE LETHAL EFFECTS IN ALBINO RATS,

Bureau of Medicine and Surgery Research Report NM 12 01 11, Subtask 5 Report No. 3

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31 January 1957

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SUMMARY PAGE

THE PROBLEM

These tests were designed to determine the effect of faster rates of explosive decompression on Albino Rats. One control group was taken from sea level to 40,000 feet, another group from sea level to 69,000 feet, and another from sea level to 105,000 feet in 0.53, 0.9, and 1.11 seconds respectively. One experimental group of rats was taken from sea level to 40,000 feet, another group from sea level to 69,000 feet, and another group from sea level to 105,000 feet in 0.0043, 0.0068, and 0.0075 second respectively.

FINDINGS

None of the control rats were killed; 40%, 70%, and 70% of the rats explosively decompressed from sea level to 40,000, 69,000, and 105,000 feet respectively died as a result of the experimental procedure.

ACKNOWLEDGMENT

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INTRODUCTION

The occurrence of pulmonary learns following explosive decompression has been reported by Smith, Corey, Bert, Hall, Lewis and Haymaker, Edelman and coworkers, and Livingston and his coworkers (1-8). These lesions may vary from small petechiae to gross hemorrhage depending upon the rate (2,5) and range of explosive decompression (5), the volume of gas in the lung (2), the frequency of re-exposure (8), and the length of time at altitude (3). Corey (2) has noted that the reduction of pulmonary volume by taping the chest results in less severe symptoms.

The present report is a comparison of the effects on the pulmonary system of explosive decompression at various rates and over various ranges. These experiments were designed to test Sweeney's (9) hypothesis that some finite time is required for elastic tissue, represented by the alveolar walls, to elongate.

METHODS AND PROCEDURE

A 14-1/4 inch diameter parasite chamber (Figure 1) was constructed and attached to a 980 cubic foot reservoir. A 14-1/4 inch paper diaphragm separating them could be ruptured by means of a four-bladed knife fired with a carbon-dioxide gun.

Wistar strain rats approximately twelve weeks of age were used as experimental animals. No restriction was made on food or water prior to the explosive decompression. All rats were pre-oxygenated for one-half hour before the decompression. Forty-five rats in all were used in this exploratory experiment.

Three control groups of five rats each were explosively decompressed from sea level to a simulated altitude of 40,000 feet in 0.53 second; from sea level to 69,000 feet in 0.9 second; and from sea level to 105,000 feet in 1.11 second. All control groups remained above 18,000 feet for five seconds or less. Ten rats were explosviely decompressed from sea level to 40,000 feet in 0.0043 second and recompressed to 18,000 feet in less than two seconds. Total time from sea level to 40,000 feet and back to sea level was eleven seconds. Ten rats were explosively decompressed from sea level to 69,000 feet in 0.0068 second and recompressed to 18,000 feet in less than two seconds. Total time was fourteen seconds. Ten rats were explosively decompressed from sea level to 105,000 feet in 0.0075 second and recompressed to 18,000 feet in less than two seconds (4). Total time was twenty-six seconds.

Table I
Pathological Results Observed in Control Groups of Rats Decompressed from Sequente to Indicated Altitudes at Indicated Rates of Time*

	rongs Tongs	Tegi		Oral and Nasal	Intestines
		Sea Level to 40,000 feet in 0.53 sec	sec.		
3	Very slight petechine	Ž	z	z	z
	No hemorrhage				•
٧3	Normal . No hemorrhage	z	z	z	z
CY 3	Very slight peripheral	z	z	z	z
	ecchymases. No hemorrhage				•
CAA	Slight eachymases	z	z	z	z
	No hemorrhoge				•
3	Normal . No hemorrhage	z	z	z	z
	•	Sea Level to 69,000 feet in 0.9 sec		•	•
5	Slight ecchymases. Slight	Right auricle	Z	z	Z
	petechiae. No hemorrhage	Slightly dilated			•
C B 2	Very slight eachymoses	Moderately dilated	z	z	z
	No hemorrhage	right ouricle			
CB3	Moderate ecchymoses. Slight				
	petechiae. No hemorrhage	z	z	z	Z
1	Moderate petechiae. Slight	Slightly diloted	z	Z	Z
	peripheral ecchymoses. No	right auricle			
	hemorrhage	•			
CB5	Slight ecchymases. Moderate	z	z	z	z
	petechiae. No hemorrhage				
		Sea Level to 105,000 feet in 1.11	56 C.		
CCI	Slightly mottled. Slight	z	z	z	z
	ecchymoses. Slight petechioe.				
CC2	Slightly mottled. Slight	z	z	z	z
	ecchymases. Slight petechiae.				
CC3	Slight ecchymoses. Slight	Moderately dilated	Flokes	z	z
	hemorrhage. Slight potechiae.	right ouricle			
700	Slight petechiae. Slight	right ourisle	Ż	z	z
	ecchyriases. Slight hemorrhage	Slightly dilated			
CCS	Moderate ecchymoses. Slight	Slightly dilated	z	z	Slight hemorrhage
	petechine No bemorphone	Alvisia Adeis			•

removal from the chamber.

Table II

Pathological Results Chiserved in Experimental Groups of Rats Explosively Decompressed from

Sea 1-vel - to Indicated Altitudes at Indicated Rates of Time®

EAI EA7 EAJ EA4 EA5 EA6 EA7 EAB EA7 EAI EA10 EB1 EB2	- 3 min. - 5 min. - 6 min. - 6 min. - 8 serificed - 1 hr. - 5 serificed - 5 seri	Massiva hemorrhage, light and dark red Massiva hemorrhage, Ecchymases and petechiae Moderate hemorrhage, Ecchymases Moderate hemorrhage, Ecchymases Massiva hemorrhage, Ecchymases Mottled lungs Mild hemorrhage, Ecchymases Petechiae, Mottled lungs Mild hemorrhage Ecchymases Petechiae, Mottled lungs Mild hemorrhage Ecchymases Mottled lungs Moderate hemorrhage Mottled lungs Moderate hemorrhage, Ecchymases Mottled lungs Moderate hemorrhage, Ecchymases Moderate hemorrhage, Ecchymases Moderate hemorrhage, Ecchymases Moderate hemorrhage, Ecchymases Petechiae, Mottled lungs	A 40,000 feet in 0 N N N N N N N Dilated right quricle N N N N N N N N N N N N N N N N N N N	N Flukes N Flukes N N N N N N	Epistanis Frothing from nose Epistanis N N N N N N N N N N N N N N N N N N N	Veins enlarged &
EA7 EA3 EA4 EA5 EA5 EA7 EA8 EA7 EA8 EA7 EA8	- 5 min 6 min 6 min 5 min 5 secificad - 1 hr	dark red Massive hemorrhage, Ecchymoses and petechiae Moderete hemorrhage, Ecchymoses Mottled lungs Massive hemorrhage, Ecchymoses Mottled lungs Mild hemorrhage, Ecchymoses Petechiae, Mottled lungs Mild hemorrhage, Ecchymoses Petechiae, Mottled lungs Mild hemorrhage Ecchymoses Petechiae, Mottled lungs Mild hemorrhage Ecchymoses Mottled lungs Moderate hemorrhage Mottled lungs Moderate hemorrhage Mottled lungs ea Level h Ecchymoses, Massive hemorrhage bright red Ecchymoses: Mussive hemorrhage,	N N N Dilated right quricle N N N N N N N N N N N N N N N N N N N	Flukes N Flukes N N N N N N N N N N N N N N N N N N N	Frothing from nose Epistaxis N N N N N N N N N N N N N N N N N N N	small intestine N N N N N N N N N N N N N N N N N N N
EAJ EAA EAS EAA EAS EAA EAA7 EAB EAA7 EAB EAA8 EAA8	• 6 min. Sacrificad • 1 hr. Sacrificad • 1 hr. Socrificad • 1 hr. Socrificad • 1 hr. Sucrificad • 1 hr. Immediate	Massive hemorrhage, Ecchymoses and petechiae Moderate hemorrhage, Ecchymoses. Mottled lungs Massive hemorrhage, dark red Moderate hemorrhage, Ecchymoses. Mottled lungs Mild hemorrhage, Ecchymoses Petechiae: Mottled lungs Mild hemorrhage, Ecchymoses Petechiae: Mottled lungs Mild hemorrhage Ecchymoses Mottled lungs Moderate hemorrhage Ecchymoses Mottled lungs Moderate hemorrhage Mottled lungs Moderate hemorrhage, Ecchymoses: Petechiae, Mottled lungs Moderate hemorrhage, Ecchymoses: Petechiaes, Motsiled lungs and Level hemorrhage for Level hemorrhage.	N N Dilated right quiricle N N N N N N N N N N N N N N N N N N N	N Flukes N N N N N N N N N N N N N N N N N N D	from nose Epistanis N N N N N N N N N N N N N N N N N N N	N N N N N N N N N N N N N N N N N N N
EAA EAS EAZ EAZ EAQ EAIU	• 6 min. Secrificed • 1 hr. sucrificed • 1 hr. sucrificed • 1 hr. sucrificed • 1 mmediate	Moderate hemorrhage, Ecchymoses. Mottled lungs Massive hemorrhage, dark red Moderate hemorrhage, Ecchymoses. Mottled lungs Mild hemorrhage, Ecchymoses. Petechiae. Mottled lungs Mild hemorrhage. Ecchymoses Petechiae. Mottled lungs Mild hemorrhage. Ecchymoses Mottled lungs Moderate hemorrhage. Moderate hemorrhage. Moderate hemorrhage. Moderate hemorrhage. Petechiae. Mottled lungs I a Level h Ecchymoses. Massive hemorrhage. Ecchymoses. Massive hemorrhage.	N Dilated right quricle N N N N N N N N N N N N N N N N N N N	Flukes N N N N N N N N N N D.0068 sec.	Epistanis N N N N N N N N N N N N N N N N N N N	N N N N N N N N N N N N N N N N N N N
EAS EAS EAS EAS EAI EAI EBI EBI	Sucrificed a. 3 hr. Sucrificed b. 1 hr. Socrificed b. 1 hr. Socrificed b. 3 hr. Sucrificed b. 4 hr. Sucrificed b. 1 hr.	Massive hemorrhage, dark red Moderate hemorrhage, Ecchymoses. Mattled lungs Mild hemorrhage, Ecchymoses Petechiae. Mattled lungs Mild hemorrhage. Ecchymoses Petechiae. Mattled lungs Mild hemorrhage. Ecchymoses Mattled lungs. Moderate hemorrhage, Ecchymoses. Petechiae, Mattled lungs. a. Level h. Ecchymoses. Massive hemorrhage bright red. Ecchymoses. Mussive hemorrhage,	Dilated right duricle N N N N N N N N N N N N N N N N N N N	N N N N N N N Should sec.	N N N N N N N N N N N Massive epistaris (frothy dark r-el bidoul) Massive repistaris	N N N N N N Slight hemorrhagesmall intestine Veins enlarged &
EAS	Sucrificed a. 3 hr. Sucrificed b. 1 hr. Socrificed b. 1 hr. Socrificed b. 3 hr. Sucrificed b. 4 hr. Sucrificed b. 1 hr.	Moderate hemorrhage , Ecchymoses . Mottled Jungs Mild hemorrhage , Ecchymoses . Petechiae . Mottled lungs Mild hemorrhage . Ecch - moses . Petechiae . Mottled lungs Mild hemorrhage . Ecchymoses . Mottled lungs . Moderate hemorrhage . Moderate hemorrhage . Moderate hemorrhage . Petechiae . Mostled lungs . ea Level h Ecchymoses . Massive hemorrhage . I and . Ecchymoses . Mussive hemorrhage . Ecchymoses . Mussive hemorrhage .	Dilated right duricle N N N N N N N N N N N N N N N N N N N	N N N N N N N Should sec.	N N N N N N N N N N N Massive epistaris (frothy dark r-el bidoul) Massive repistaris	N N N N N N Slight hemorrhage small intestine Veins enlarged #
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EAZ FAB EAG FA10 FA10 FB1	+ 1 hr. Socificad + 1 hr. Socificad + 1 hr. Sucrificad + 1 hr. sucrificad + 1 hr. sucrificad + 1 hr. sucrificad + 1 hr.	Petechiae , Mattled lungs Mild hemorrhage , Ecch-mases Petechiae , Mattled lungs Mild hemorrhage , Ecchymases Mattled lungs Moderate hemorrhage Mottled lungs Moderate hemorrhage, Ecchymases , Petechiae , Mattled lungs ea Level h Ecchymases , Massive hemorrhage bright red Ecchymases , Mussive hemorrhage ,	N N N N N N N N N N N N N N N N N N N	N N N N 0.0068 sec. Flukes	N N N N Massive epistavis (frathy dark r-d bidod) Massive epistavis	N N N Slight hemorrhages small intestine Veins enlarged #
EAB EAO EA10 EB1 EB2	• 1 hr. Serrificed • 1 hr. Secrificed • 1 hr. secrificed • 1 hr. Immediate	Petechiae , Mottled lungs Mild hemorrhage - Ecchymases Mottled lungs Moderate hemorrhage Mottled lungs Moderate hemorrhage, Ecchymases . Petechiae , Mottled lungs ea Level h Ecchymases , Massive hemorrhage bright red Ecchymases : Mussive hemorrhage ,	N N N a 40,000 feet in 0 N	N N N 0.0068 sec. Flukes	N N N Massive epistavis (frothy derk red bidod) Massive epistavis	N N Slight hemorrhage small intestine Veins enlarged #
EA? EA10 EB1 EB2	Sucrificed Incomplete the sucrificed Incomplete the sucrificed Immediate	Mattled lungs Maderate hemarrhage Mattled lungs Maderate hemarrhage, Ecchymases. Petechiae, Mattled lungs ea: Level h Ecchymases, Massive hemarrhage uright red Ecchymases: Mussive hemarrhage,	N N N 49,000 feet in S N	N N 0.0068 sec. Flukes	N Nassive epistavis (frathy dark r-d bidod) Massive epistavis	N N Slight hemorrhagi small intestine Veins enlarged d
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					. 2. , 2	i fulli, lärge intest - Slight hemarrhäge -small intestine
	Immediate	Ecchymoses, Mossive hemorrhoge, dull red	N	fluxes	Massive epistanis (blood light in culor)	N
E B4	Immediate	Eachymases: Massive hemarrhage, dark red	И	Flukes	Mussive epistanis (tilead light in calar)	Slight hemorrhage
E 8 5	Immediate	Ma live hemorrhage, dark red	N	Flukes	Massive epistanis (in sed light in calor)	Slight nemorrhage
£ 8 4	• 7 min	Massive hemorrhage, duk red	N	N	Aussiva epistanis (ia-aad inglit in calar)	N
EB/	, 9 min.	Massive hemorrhage, dark red	P4	N	Epistums	7
£ 38	Sacrificad	Euchymoses, moderate hemmurhage			•	
	i l.he.	Mattled longs	N	Flukes	N	N
E B 9	Saurificeal - Thr.	Eachymases, Maderate hemarrhage, Petechiae, Mottled lungs	N	Flu≭es.	N	И
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	. I hr	Mattled lungs	- 105 WM14			
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tC2	Immediate	Euchymases - Noderate himatrhage,	P4	N	Epistanis	and . Fige - Hemosthage, sma
rcs.	lmmadiate	tinght red Euchymuses: "Amsive hemorthage,	r.	Fluses	Europairs	intestine
	Immediate	durk rad	•	N.		
tC4		Almairo hemisthique, distrete	Direted right auriste		Epistusia	Discolutation, small intestine
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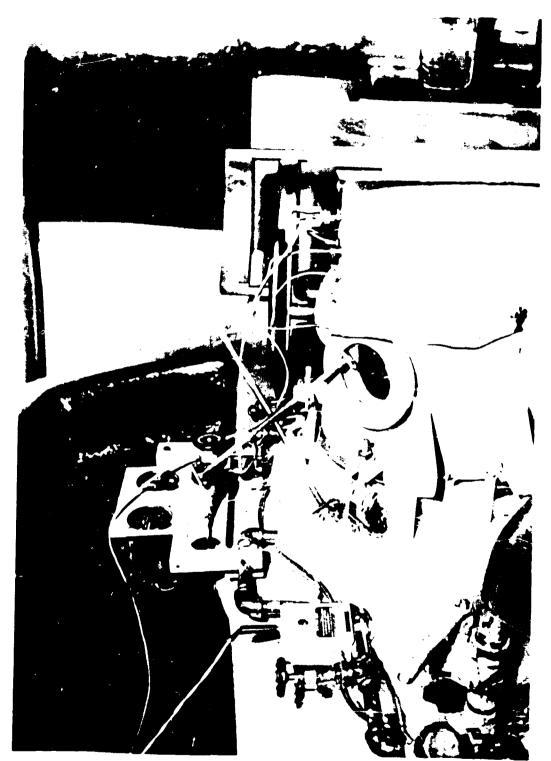


Figure 1

Animal Explosive Decomprossion Parasite Chamber Four bladed Diaphragm Cutting Knife Also Shown

Following exposure to the simulated terminal altitudes, control and experimental rats were returned to sea level and removed immediately from the chamber. The groups were allowed to remain undisturbed for one hour, after which time surviving rats were sacrificed and examined grossly for pathological changes to the respiratory, gastrointestinal, and cardiovascular systems.

RESULTS

Results are detailed in Tables I and II. No rat in any control group died as a result of the exposure. There was no evidence of gross hemorrhage in the lungs in the control group, but there were areas of ecchymoses and petechiae evident. All lungs floated. All hearts appeared normal with the exception of some dilation of the auricles. All gastrointestinal systems were normal when examined grossly, with the exception of one of the rats taken to 105,000 feet which exhibited a slight hemorrhage of the small intestine.

Of the ten rats explosively decompressed from sea level to 40,000 feet in 0.0043 s second (0.93 x 10⁷ feet/sec, or 142,000 mm Hg/sec), four died at +3, +5, +6, and +6 minutes (after recompression to sea level). All four exhibited massive pulmonary hemorrhage and epistaxis. All hearts appeared to be normal; gastrointestinal systems were normal with the exception of a slight hemorrhage of the small investine in the caecal area of one rat. The remaining six rats of this group were sacrificed and showed light to moderate hemorrhage of the pulmonary system but apparently normal hearts and gastrointestinal systems. The lungs of all these ten rats floated in water.

The second group of ten rats were explosively decompressed from sea level to 69,000 feet in 0.0068 second (1×10^7 feet/sec or 106,200 mm Hg/sec). Five of this group were dead on recompression to sea level, and two additional rats died at +7 and +9 minutes. All seven exhibited epistaxis, and four of the seven had some hemorrhage of the small intestine. The three rats which were sacrificed after an hour showed hemorrhage of the lungs; other systems appeared normal.

The third group of ten rats were explosively decompressed from sea level to 105,000 feet in 0.0075 second (1.4×10^7) feet, sec or 100,300 mm Hy/sec). Four of this group were dead on recompression, with three additional rats dead at +9, +11, and +15 minutes. All seven showed massive hemotrhage of the lungs; two had dilated auticles,

five exhibited epistaxis, and five had abnormalities of the vascular system in the intestinal area. The three rats sacrificed after an hour showed abnormalities of the pulmonary system, with other systems apparently normal.

DISCUSSION

The purpose of this experiment was to determine if there is a finite time required for the alveolar membranes to expand to point of rupture in explosive decompression. It was realized that a patent tracheal passage might allow rapid dissipation of prohibitive incipient pressure in the lungs no matter how rapid the onset of the pressure. If there is a minimal finite time required for expansion of alveolar tissue following explosive decompression, it must be less than 0.004 second for 100 per cent fatality in the rat.

The exposure times used in this experiment produced either lethal or sublethal effects in all rats. The probability is slight that all rats had a closed tracheal airway at the instant of decompression. The minimal symptoms seen in the control groups add credence to previous findings that the physical process of explosive decompression per see can produce pathological changes in the rat without the effects of hypoxia or decompression sickness (aerebullosis).

There was some similarity of symptoms in the group of rats exposed to 69,000 feet and the group exposed to 105,000 feet. The rate of change in pressure was similar (106,200 mm Hg/sec compared to 100,300 mm Hg/sec), but the ratio of gas expansion (RGE) would differ greatly. Sea level to 69,000 feet would give a ratio of gas expansion in dry air of 21.3, and sea level to 105,000 feet would give an RGE of 108.6 in dry air. RGE refers to free gas expansion; in explosive decompression, RGE would be opposed by pertinent tissue pressure. If the tissue can withstand a pressure change of 724.3 mm Hg (sea level to 69,000 feet), it apparently can tolerate 753 mm Hg change (sea level to 105,000 feet).

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